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AN IMAGE PROCESSING SOFTWARE PACKAGE.(U)

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SMU-EE-TR-81-11
Contract Number N00014-79-C-0494
June [redacted] 1981

AN IMAGE PROCESSING SOFTWARE PACKAGE*

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AN IMAGE PROCESSING SOFTWARE PACKAGE

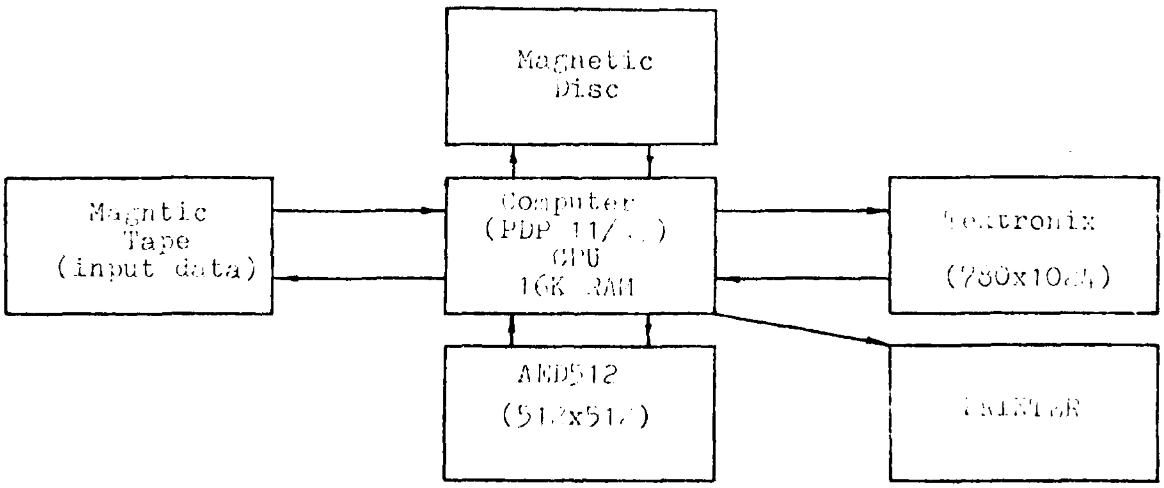
Chihsung Yen

1. Introduction

Modern technology utilizes all types of pictures, or images, as sources of information for interpretation and analysis. These may be portions of the earth's surface viewed from an orbiting satellite or reconnaissance plane, the inner composition of a complex organic structure seen with the aid of X-rays or microscope. The proliferation of the pictorial data bases has created the need for a vison-based automation that can rapidly, accurately, and cost effectively extract the useful information contained in images. These requirements are being met through the new technology of image processing. The purpose of this report is to introduce the utilities that we have for using image processing and computer results by using some basic image processing functions. A software package is developed and described in detail in the report.

1.1 Utilities

The whole system used to produce the results described herein is shown in the Block Diagram.



A mini-computer (PDP 11/45) with a magnetic disc memory for the storage of pictures receives input data from the magnetic tape. Output data in the form of processed images are stored in the magnetic disc files and displayed on the Tektronix terminal with 2-level or on the AED512 terminal with the color 16-level or on the printer with 16-level. Control of the image processing functions is made through the Tektronix or AED512 keyboard. Data and reports are printed on the printer or displayed on the screens.

1.2 Data sources

The principal image data are provided by

i Alabama data base (infrared images)

ii USC data base

iii Reconnaissance images

iv Topographic images

1.3 How to used this package?

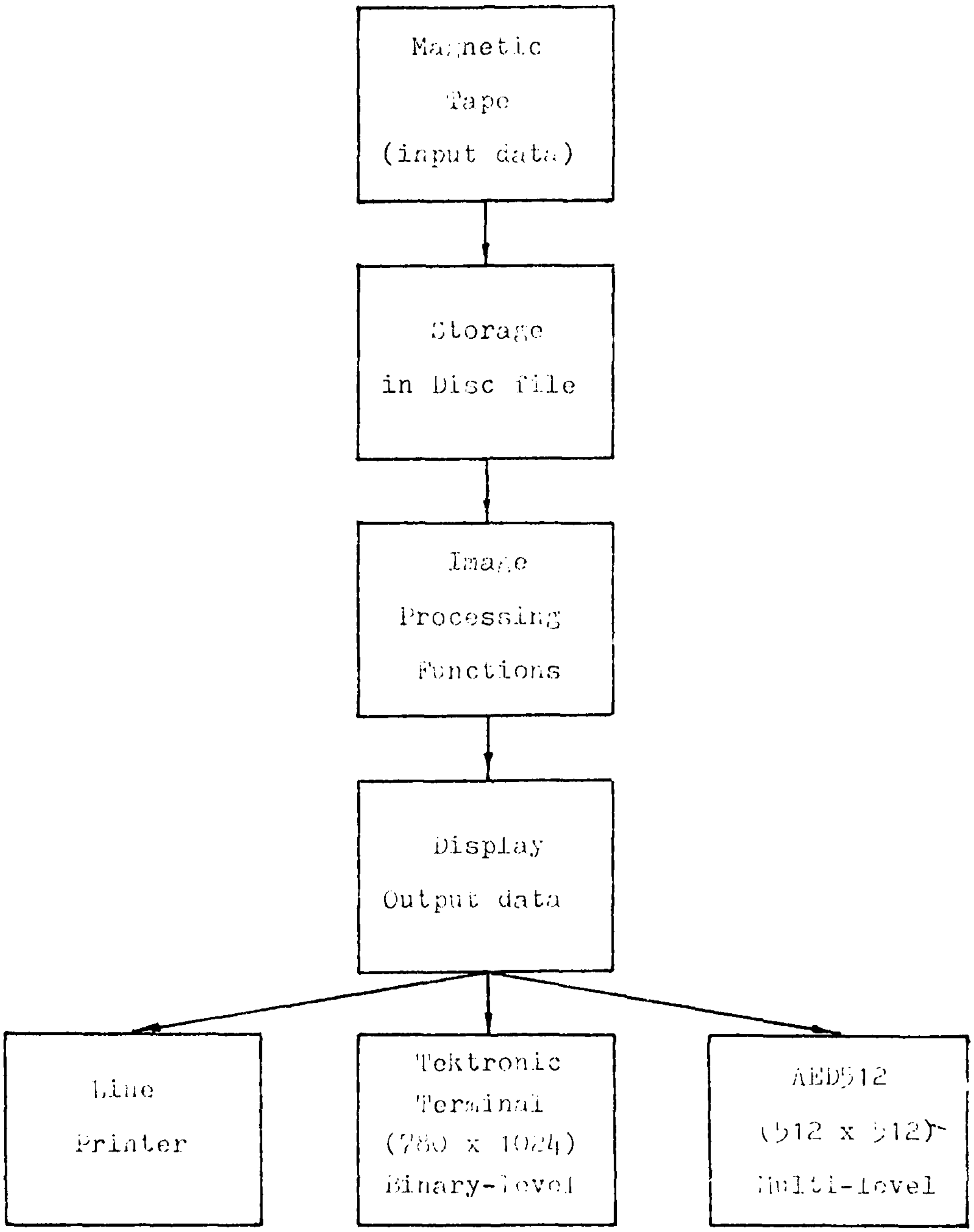
All the program listings are in the Appendix. Next page block diagram is shown how to used this package.

1.4 Some basic image processing functions

a. Histogram Equalization (1,2)

For many classes of images, in general, the ideal distribution of gray levels is a uniform distribution. An uniform distribution of gray levels makes equal use of each quantization level and tends to enhance low-contrast information. To use this transformation we may

i compute the histogram of the image gray level values,



Magnetic
Tape
(input data)
Storage
in Disc file
Image
Processing
Functions
Display
Output data
Line
Printer
Tektronic
Terminal
(780 x 1024)
Binary-level
AED512
(512 x 512)
Multi-level

ii add up the histogram values to obtain a distribution curve, and

iii use this distribution curve for the gray level transformation $G = T(f)$

where G: transferred gray level value

T: transformation symbol

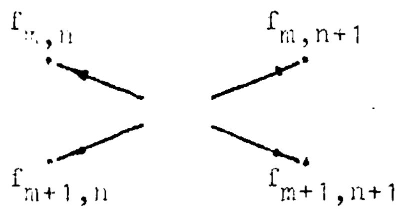
f: original gray level value

b. Robert Gradient Operator (3)

$$d_1 = f_{m,n} - f_{m+1,n+1}$$

$$d_2 = f_{m+1,n} - f_{m,n+1}$$

$$G(m,n) = (d_1^2 + d_2^2)^{\frac{1}{2}}$$



where $f_{m,n}$ is the gray level of point (m,n), $G(m,n)$ is Robert gradient of point (m,n).

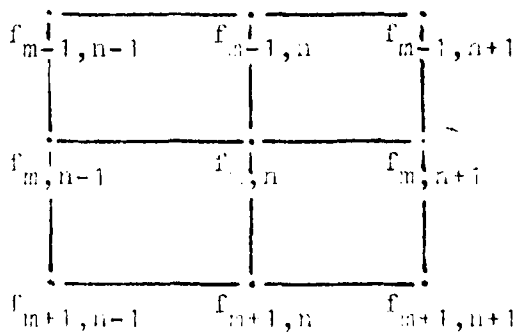
c. Sobel Operator (3)

$$d_X = (f_{m-1,n-1} + 2f_{m,n-1} + f_{m+1,n-1}) - (f_{m-1,n+1} + 2f_{m,n+1} + f_{m+1,n+1})$$

$$d_Y = (f_{m+1,n-1} + 2f_{m+1,n} + f_{m+1,n+1}) - (f_{m-1,n-1} + 2f_{m-1,n} + f_{m-1,n+1})$$

$$S(m,n) = (d_X^2 + d_Y^2)^{\frac{1}{2}}$$

where $S(m,n)$ is Sobel gradient of point (m,n).



d. Modified Gradient (4)

A modification of the conventional gradient operations for the first derivative is called modified gradient. Consider a 16-point array

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

The modified gradient is defined as

$$\sqrt[4]{abcd}$$

where

$$a = |F - K| + |J - G|$$

$$b = |A - P| + |M - D|$$

$$c = |B - O| + |I - H|$$

$$d = |C - N| + |E - L|$$

e. Masks (5)

Two-dimensional discrete differentiation can be performed by convolving the original image with the compass gradient masks shown in Fig. A. The compass names indicate the slope direction of maximum response. The gradient image is obtained by taking the magnitude of the output of that mask.

Direction of Gradient	Prewitt Masks	Kirsch Masks	Three-Level Simple Masks	Five-level Simple Masks
North	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ -1 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$
Northwest	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & -1 \\ 1 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix}$
West	$\begin{bmatrix} 1 & 1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & -1 \end{bmatrix}$	$\begin{bmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$
Southwest	$\begin{bmatrix} 1 & -1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{bmatrix}$	$\begin{bmatrix} 0 & -1 & -1 \\ 1 & 0 & -1 \\ 1 & 1 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}$
South	$\begin{bmatrix} -1 & -1 & -1 \\ 1 & -2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & -3 & -3 \\ -3 & 0 & -3 \\ 5 & 5 & 5 \end{bmatrix}$	$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$
Southeast	$\begin{bmatrix} -1 & -1 & 1 \\ -1 & -2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & -3 & -3 \\ -3 & 0 & 5 \\ -3 & 5 & 5 \end{bmatrix}$	$\begin{bmatrix} -1 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$
East	$\begin{bmatrix} -1 & -1 & 1 \\ -1 & -2 & 1 \\ -1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{bmatrix}$	$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$
Northeast	$\begin{bmatrix} 1 & 1 & 1 \\ -1 & -2 & 1 \\ -1 & -1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & 5 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & -3 \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & 1 \\ -1 & 0 & 1 \\ -1 & -1 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}$

Fig. A

f. Unsharp masking (2)

$$G(m,n) = f(m,n) - F(m,n)$$

where the function $F(m,n)$ is a local average, for example,

$$F(m,n) = \frac{1}{8} \sum_{i=-1}^{1} \sum_{j=-1}^{1} f(m+i,n+j), \quad i+j \neq 0$$

g. First order AAIA model (6)

A first-order Autoregressive image model can be written as

$$f(m,n) - \mu_c = \beta_c((f(m-1,n) - \mu_c) + (f(m,n-1) - \mu_c)) + N(m,n)$$

$$m = 1,2, \ldots\ldots M$$

$$n = 1,2, \ldots\ldots N$$

where, $N(m,n)$ is an uncorrelated Gaussian white noise process, and μ_c is the sample mean. Rearrange the above equation to get

$$f(m,n) = \alpha_c + \beta_c(f(m-1,n) + f(m,n-1)) + N(m,n)$$

where,

$$\alpha_c = (1 - 2\beta_c)\mu_c$$

Define

$$G(m,n) = f(m-1,n) + f(m,n-1)$$

Thus

$$f(m,n) = \alpha_c + \beta_c G(m,n) + N(m,n)$$

The least mean square estimator (also the maximum likelihood estimator because of Gaussian assumption (6) is given by

$$b = \frac{\sum_m \sum_n G(m,n) f(m,n)}{\sum_m \sum_n (G(m,n))^2}$$

$$a = \bar{F} - b\bar{G}$$

where

$$F = \frac{\sum_m \sum_n f(m,n)}{MN}$$

$$G = \frac{\sum_m \sum_n g(m,n)}{MN}$$

and

$$b = \hat{\beta}_c = \text{the estimator of } \beta_c$$

$$a = \hat{\alpha}_c = \text{the estimator of } \alpha_c$$

h. The Kalman Filter (7)

The signal model of the Kalman filter is

$$X_{K+1} = F_K X_K + G_K W_K$$

$$Z_K = Y_K + V_K = H_K' X_K + V_K$$

where, X_0, $\{V_K\}$, and $\{W_K\}$ are jointly Gaussian and mutually independent; X_0 is Gaussian distributed with mean $\overline{X}_0$ and covariance P_0 respectively; $\{V_K\}$ is zero mean with covariance $R_K \delta_{Kl}$; $\{W_K\}$ is zero mean with covariance $Q_K \delta_{Kl}$.

The filter equations of the Kalman filter is given by

$$\hat{X}_{K+1/K} = (F_K - K_K H_K')\hat{X}_{K/K-1} + K_K Z_K$$

$$\hat{X}_{0/-1} = \hat{X}_0$$

$$K_K = F_K \Sigma_{K/K-1} H_K (H_K' \Sigma_{K/K-1} H_K + R_K)^{-1}$$

$$\Sigma_{K/K-1} = F_K \{ \Sigma_{K/K-1} - \Sigma_{K/K-1} H_K (H_K' \Sigma_{K/K-1} H_K + R_K)^{-1} H_K' \Sigma_{K/K-1} \} F_K' + G_K Q_K G_K'$$

$$\Sigma_{0/-1} = P_0$$

$$\hat{X}_{K/K} = \hat{X}_{K/K-1} + \Sigma_{K/K-1} H_K (H_K' \Sigma_{K/K-1} H_K + R_K)^{-1} (G_K - H_K' \hat{X}_{K/K-1})$$

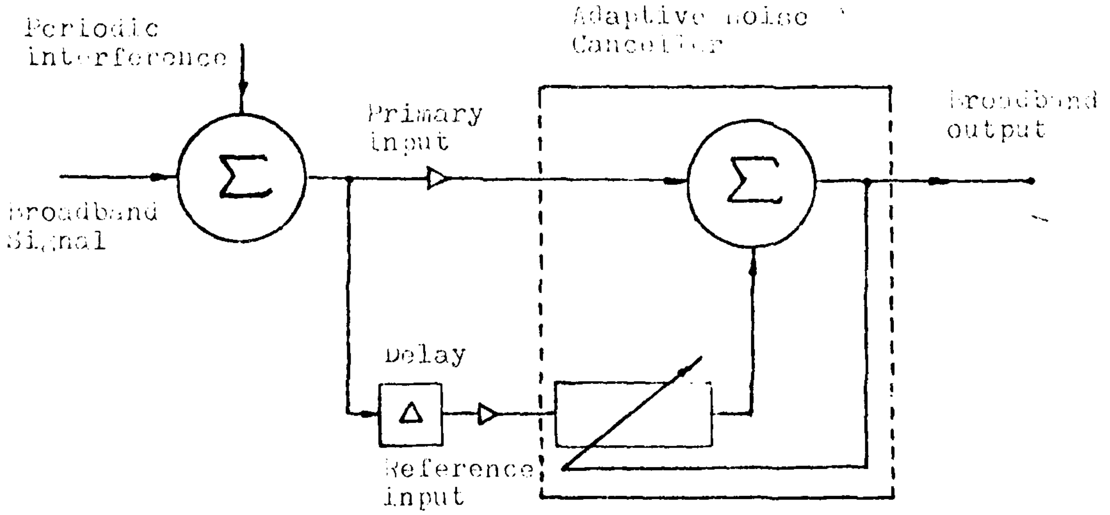
$$\Sigma_{K/K} = \Sigma_{K/K-1} - \Sigma_{K/K-1} H_K (H_K' \Sigma_{K/K-1} H_K + R_K)^{-1} H_K' \Sigma_{K/K-1}$$

The Kalman filter above gives a set of recursive equations for estimating the state of a linear dynamic system. However, the Kalman filter requires a priori knowledge of all the system and noise parameters, which must be identified before using the filter. The following are useful suggestions for implementation: (Assume K = 1)

1. F_K , G_K , and H_K can be set as unity
2. If the variance of additive noise is known or can be estimated, then, set the value of R_K to be the variance.
3. Q_K is the system noise, and should be set to a value which is of the order of R; otherwise the filtered results may be undesirable. Usually, $R_K > Q_K$.

i. Adaptive Noise Cancelling Filter (8)

Cancelling periodic interference without an external reference source model is



The input signal vector X_j is defined as

$$X_j \triangleq \begin{bmatrix} x_{0j} \\ x_{1j} \\ \cdot \\ \cdot \\ \cdot \\ x_{nj} \end{bmatrix}$$

The weight vector is

$$W = \begin{bmatrix} w_0 \\ w_1 \\ \cdot \\ \cdot \\ \cdot \\ w_n \end{bmatrix}$$

where w_0 is the bias weight

The output y_j is

$$y_j = X_j'W = W'X_j$$

The error e_j is defined as the difference between the desired response d_j and the actual response y_j.

$$e_j = d_j - X_j'W = d_j - W'X_j$$

Expanding the last equation obtains

$$e_j^2 = d_j^2 - 2d_jX_j'W + W'X_jX_j'W$$

Taking the expected value of both sides yields

$$E[e_j^2] = E[d_j^2] - 2E[d_jX_j']W + W'E[X_jX_j']W$$

defining the vector P as the cross correlation between the desired response and X vector then yields

$$P \triangleq E[d_jX_j]$$

The input correlation matrix R is defined as

$$R \triangleq E[X_jX_j']$$

The mean-square error can thus be expressed as

$$E[e_j^2] = E[d_j^2] - 2P^TW + W^TRW$$

The gradient ∇ of the error function is obtained by

$$\nabla \triangleq -2P + 2RW$$

and the gradient estimate is

$$\hat{\nabla}_j = -2e_jX_j$$

and

$$W_{j+1} = W_j + 2\mu e_j X_j$$

where μ is the factor that controls stability and rate of convergence.

2. Experiments

Currently, we can display binary-level pictures on the Tektronix terminal and 16-level pictures on the AED512 terminal. In this report, all the pictures are displayed on the AED512 terminal except histogram figures. A reconnaissance image with a tank, a USC image with a cave, and a topographic image with a roadway are being used to demonstrate the capabilities of this package. Table 1 describes the number sequence of sub-pictures of Figures 1,2 & 3.

1

1	2
3	4

1	2
3	4
5	6

Table 1

Figure 1a.2 is original reconnaissance image with a tank.

Figure 1a.1 is equalized result. The histograms of Figure 1a are shown in the Figure 1b. Figure 1c is the results of using Prewitt masks, Kirsch masks, Three-level simple masks and Five-level simple masks, respectively. The results of using Robert gradient operator, Sobel operator and modified gradient operator are shown in the Figure 1d.2,3 & 4, respectively. Figure 1d.1 is original image. Figure 1e is the equalized results of Figure 1d except original image. Figure 1f.3-6 is the computer results of using 1st order ARMA model, Adaptive filter, Kalman filter with horizontal processing, and Kalman filter with vertical processing, respectively. Figure 1f.1 is original image. Figure 1f.2 is additive white Gaussian noise with variance 15 and zero mean. The histograms of Figure 1f are shown in the Figure 1g. The sequence of Figure 2 is same as Figure 1 except that the scene is the topographic image with a roadway and the variance of additive noise is 30. Almost the sequence of Figure 3 is also same as Figure 1 except that the scene is the LSC image with a cave and the Figure 3c is the computer results of using unsharp masking technique.

3. Conclusion Remarks

Currently, we can only display 16-level pictures with any color, for example, Figure 8. In the next couple weeks, additional memory planes will be added to the AED512 terminal to display all 256 gray levels and the full color pictures. We also plan to add more advanced image processing functions in this package in the near future.

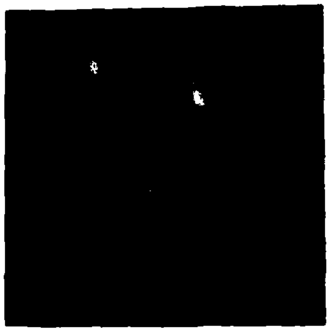


Fig. 5

4. Acknowledgements

I would like to express my sincere thanks to Professor Peng-Fei Li for his suggestion in the adaptive noise cancelling filter.

Reference:

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"Digital Image Processing", Addison-Wesley Publishing Company, pp. 119-126, 1977.

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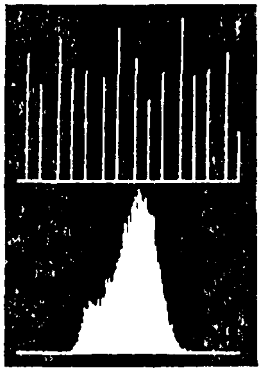
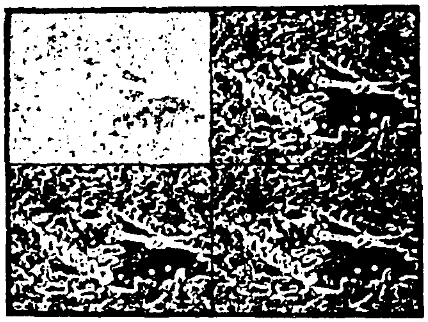
"Adaptive Noise Cancelling: Principles and Applications, IEEE Proceedings, Vol. 63, No. 12, December 1975.

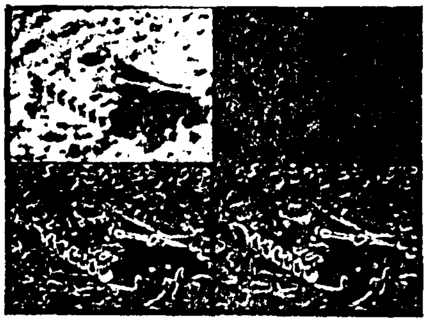
1a



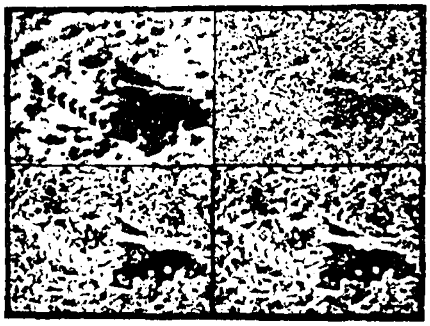
1b



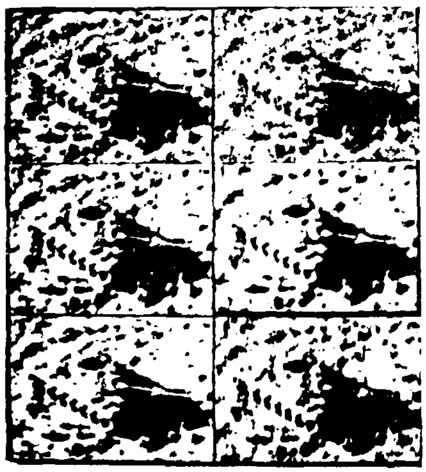
1c



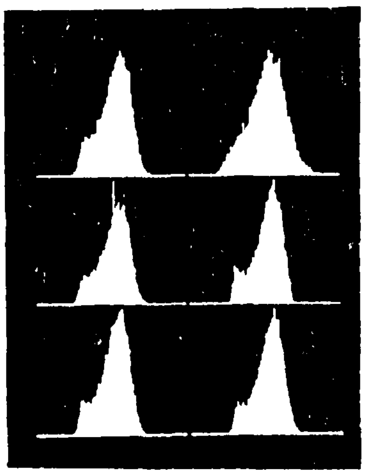
1d



1e

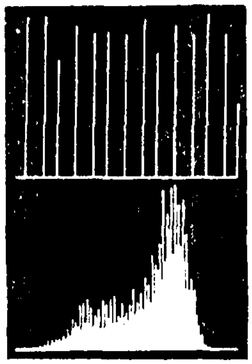


1f

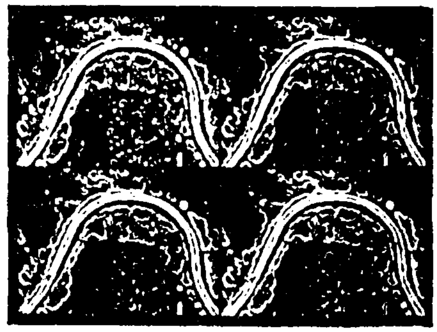


1g

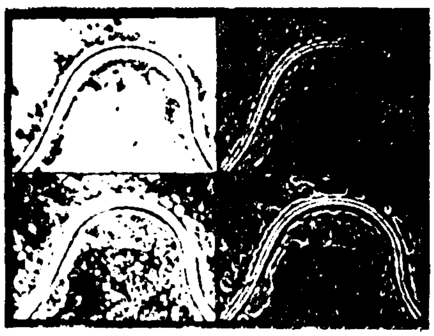
'a



2b

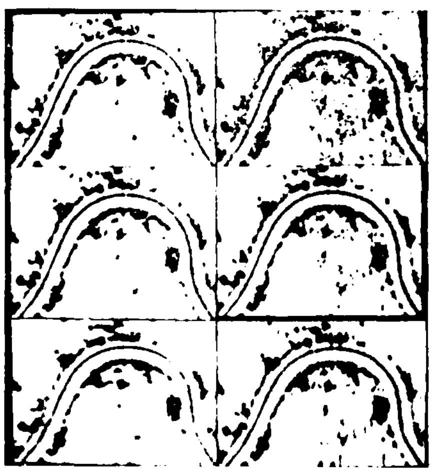


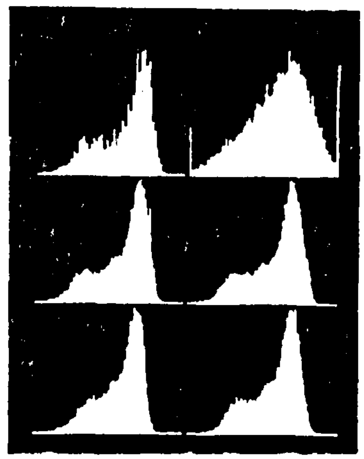
2c

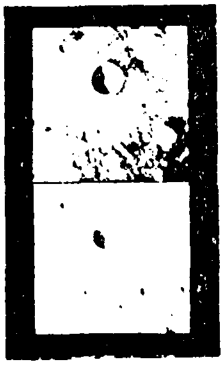


d

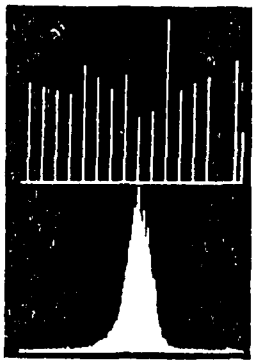
'e



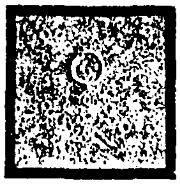




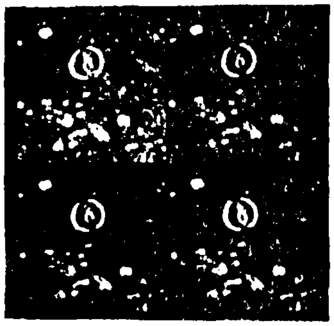
3a



3b

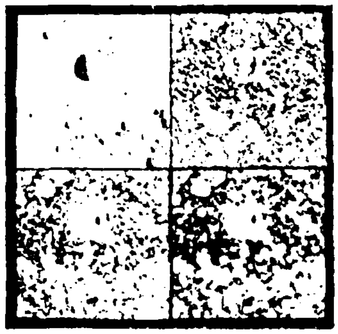


3c

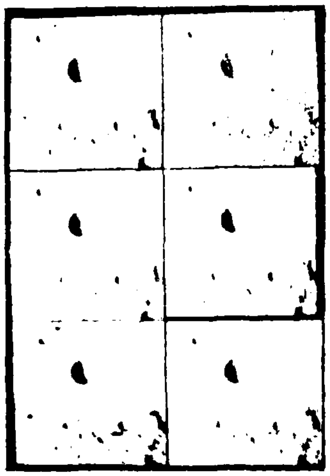


3d

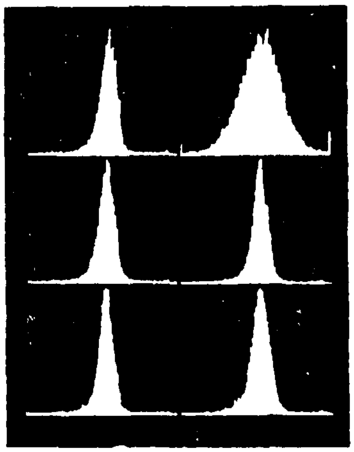
3e



3f



3g



3h

Appendix:

A.1 Introduction

The computer programs listed in this appendix were coded in FORTRAN on the PDP-11/45 Minicomputer system monitored under RT-11 operating system.

A.2 Programs

I STORAG.FOR

To storage the image from magnetic tape to disc file.

II FMXFMI.FOR

To find out the maximun and minimum from a file.

III DISPLAY.FOR

To display the image on the AED512 terminal.

IV SETCOR.FOR

For set color table of AED512.

V HISTOG.FOR

To compute the histogram curve of a file and display on the Tektronix terminal.

VI ROBERT.FOR

The Robert gradient operator.

VII SOBEL.FOR

The Sobel operator.

VIII MODGRD.FOR

The modified gradient operator

IX EQ.FOR

The histogram equalization function.

X PREWIT.FOR

The Prewitt masks.

XI LOCAL.FOR

The unsharping masks function.

XII THSHO.FOR

The simple treresholding function.

XIII ANOS.FOR

The adding Gaussian noise function.

XIV ALPHA.FOR

To compute coefficients for 1st order ARMA model.

XV ARMA.FOR

The 1st order ARMA model

XVI KALMAN.FOR

The Kalman filter for horizontal processing.

XVII VH.FOR

The Kalman filter for vertical processing.

XVIII ADPT.FOR

The adaptive noise cancelling filter.

I.

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C
C         NAME: [illegible].FOR
C         PGMR: [illegible] C. YEH
C         DATE: [illegible], 1981
C
          INTEGER F(1024)
          WRITE(5,10)
10        FORMAT(5X,'I/P NOL,NOP,NTH,NOF,IL'/)
          READ(5,20)NOL,NOP,NTH,NOF,IL
20        FORMAT(5I4)
          DEFINE FILE NOF(NOL,NOP,U,LINE)
          WRITE(5,30)
30        FORMAT(/5X,'I/P LINEI,LINEF,IPXI,IPXF,IORIGL'/)
          READ(5,40)LINEI,LINEF,IPXI,IPXF,IORIGL
40        FORMAT(5I5)
          LINE=1
          DO 50 I=1,IORIGL
          CALL [illegible](F,IL,NTH)
          IF(I.LT.LINEI.OR.I.GT.LINEF)GO TO 50
          WRITE(NOF'LINE)(F(K),K=IPXI,IPXF)
50        CONTINUE
          CALL [illegible]
          CALL EXIT
          END
```

II.

```
C
C         NAME: FMXFMI.FOR
C         PGMR: ROBERT C. YEH
C         DATE: APRIL 10, 1981
C
          INTEGER F(1024)
          WRITE(5,5)
5         FORMAT(5X,'I/P NOL,NOP,NOF'/)
          READ(5,10)NOL,NOP,NOF
10        FORMAT(3I5)
          DEFINE FILE NOF(NOL,NOP,U,LINE)
          LINE=1
          READ(NOF'LINE)(F(KK),KK=1,NOP)
          IMAX=F(1)
          IMIN=F(1)
          DO 40 I=1,NOL
          LINE=1
          READ(NOF'LINE)(F(K),K=1,NOP)
          DO 30 J=1,NOP
          IF(F(J).GT.IMAX)IMAX=F(J)
          IF(F(J).LT.IMIN)IMIN=F(J)
30        CONTINUE
40        CONTINUE
          WRITE(5,50)IMAX,IMIN
50        FORMAT(//5X,2I10)
          CALL EXIT
          END
```

III.

```
C
C         NAME: [illegible].FOR
C         PROG: ROBERT C. YEN
C         DATE: APRIL 25, 1981
C
          INTEGER F(10 4)
          WRITE(5,10)
10        FORMAT(/1X,'I/P NOL,NOP,NOF,IX,IY,RNG,FMIN'/)
          READ(5,20)NOL,NOP,NOF,IX,IY,RNG,FMIN
20        FORMAT(5I5,2F12.5)
          DEFINE FILE NOF(NOL,NOP,U,LINE)
          IIX=IX
          IIY=IY
          CALL GRMOD
          DO 40 I=1,NOL
          LINE=I
          READ(NOF'LINE)(F(K),K=1,NOP)
          DO 30 J=1,NOP
          ICOLOR=INT((FLOAT(F(J))-FMIN)*15./RNG)
          CALL PNTABS(IIX,IIY,ICOLOR)
          IIX=IIX+1
30        CONTINUE
          IIX=IX
          IIY=IIY-1
40        CONTINUE
          CALL ANMOD
          CALL [illegible]
          CALL EXIT
          END
```

IV.

```
C
C         NAME: [illegible]TCOL.FOR
C         PROG: ROBERT C. YEN
C         DATE: APRIL 25, 1981
C
          DIMENSION IRGB(16,3),RATIO(3)
          TYPE 10
10        FORMAT(//1X,'ENTER 3 REAL NO. FOR INTENSITY LEVELS OF RED,
         1 GREEN, BLUE :'/)
          ACCEPT 20,(RATIO(K),K=1,3)
20        FORMAT(3F12.5)
          RMAX=RATIO(1)
          DO 30 I=2,3
          IF(RATIO(I).GT.RMAX)RMAX=RATIO(I)
30        CONTINUE
          DO 40 I=1,3
40        RATIO(I)=RATIO(I)/RMAX
          TYPE 50
50        FORMAT(//1X,'ENTER N WHICH IS INDEX OF M=2**N,AND M IS
         1 NO. OF INTENSITY LEVELS'/)
          ACCEPT 60,N
```

```
60      FORMAT(I5)
        IF(N.EQ.0)M=1
        IF(N.NE.0)M=2**N
        FM=255./FLOAT(M-1)
        ID=16/M
        DO 90 I=1,3
        DO 80 J=1,M
        DO 70 K=1,ID
        KK=(J-1)*ID+K
70      IRGB(KK,I)=INT(RATIO(I)*FM*(J-1))
80      CONTINUE
90      CONTINUE
        TYPE 100
100     FORMAT(/17X,'RED              GREEN              BLUE'/)
        TYPE 110,((IRGB(I,J),J=1,3),I=1,16)
110     FORMAT(5X,3I15)
        ACCEPT 120,JUNK
120     FORMAT(A1)
        CALL GRMOD
        DO 130 J=1,16
        CALL COLTAB(J-1,IRGB(J,1),IRGB(J,2),IRGB(J,3))
130     CONTINUE
        CALL ANMOD
        CALL BELL
        CALL EXIT
        END
```

V.

```
C
C       NAME: HISTOG.FOR
C       PRGR: ROBERT C. YEN
C       DATE: JUNE12, 1981
C
        REAL HX(2048),HY(2043),HZ(256)
        INTEGER F(512)
        TYPE 10
10      FORMAT(/5X,'I/P NOL,NOP,NOF,NOG'/)
        ACCEPT 20,NOL,NOP,NOF,NOG
20      FORMAT(4I5)
        TYPE 110
110     FORMAT(/5X,'I/P IXI,IXF,IYI,IYF'/)
        ACCEPT 120,IXI,IXF,IYI,IYF
120     FORMAT(4I10)
        DEFINE FILE NOF(NOL,NOP,U,LINE)
        DO 30 I=1,2048
        HY(I)=0.
        HX(I)=FLOAT(I)
30      CONTINUE
        DO 35 I=1,NOG
35      HZ(I)=0.
        DO 40 J=1,NOL
        LINE=J
        READ(NOF'LINE)(F(K),K=1,NOP)
```

```
      CALL HISTOG(F,HX,NOP)
40    CONTINUE
      NC=2048/N
      DO 50 I=1,NC
      II=(I-1)*N+1
      HY(II)=HX(I)
50    CONTINUE
      CALL [illegible](HX,HY,2048,IX1,IXF,IY1,IYF)
      CALL EXIT
      END
      SUBROUTINE HISTOG(F,HY,IXL)
      REAL HY(1)
      INTEGER F(1)
      DO 10 I=1,IXL
      J=F(I)
      HY(J)=HY(J)+1.
10    CONTINUE
      RETURN
      END
```

VI.

```
C
C     NAME: NORENT.FOR
C     PROGR: ROBERT C. YEN
C     DATE: MAY 10,1981
C
      INTEGER F1(512),F2(512),G(512)
      TYPE 10
10    FORMAT(/' ','INPUT NOL,NOP,NOF1,NOF2'/)
      ACCEPT 20,NOL,NOP,NOF1,NOF2
20    FORMAT(4I10)
      DEFINE FILE NOF1(NOL,NOP,U,LINE)
      NOL2=NOL-1
      NOP2=NOP-1
      DEFINE FILE NOF2(NOL2,NOP2,U,LINE2)
      DO 100 I=1,NOL2
      LINE=I
      READ(NOF1'LINE)(F1(K),K=1,NOP)
      LINE=I+1
      READ(NOF1'LINE)(F2(K),K=1,NOP)
      DO 50 J=1,NOP2
      X=FLOAT(F1(J)-F2(J+1))
      XS=X*X
      Y=FLOAT(F1(J+1)-F2(J))
      YS=Y*Y
      XY=SQRT(XS+YS)
      IF(XY.GT.256.)XY=256.
      IF(XY.LT.1.)XY=1.
      G(J)=INT(XY)
50    CONTINUE
      LINE2=I
      WRITE(NOF2'LINE2)(G(K),K=1,NOP2)
100   CONTINUE
      CALL EXIT
      END
```

VII.

```
C
C           NAME: [illegible].FOR
C           [illegible] : [illegible] C. Y[illegible]
C           DATE: MAY 1[illegible], 1981
C
            DIMENSION F1(512),F2(512),F3(512),G(512)
            TYPE 10
10          FORMAT(/' ','I/P [illegible], [illegible], [illegible], [illegible]'/)
            ACCEPT 20,NOL,NOP,NOF1,NOF2
20          FORMAT([illegible])
            DEFINE FILE F1(NOL,[illegible], ,[illegible])
            NOL2=NOL-2
            NOF2=NOP-1
            DEFINE FILE NOF2(NOL2,N[illegible], , ,N[illegible]R2)
            NL1=NOL-1
            DO 50 I=2,NL1
            NREC1=I-1
            READ(NOF1'NREC1)(F1(K),K=1,NOP)
            NREC1=I
            READ(NOF1'NREC1)(F2(K),K=1,NOP)
            NREC1=I+1
            READ(NOF1'NREC1)(F3(K),K=1,NOP)
            CALL [illegible]L(F1,F2,F3,G,NOP)
            NREC2=I-1
            WRITE(NOF2'NREC2)(G(K),K=1,NOP)
            [illegible]
50          CONTINUE
            CALL EXIT
            END
            SUBROUTINE SO[illegible]EL(F1,F2,F3,G,NOP)
            INTEGER F1(1),F2(1),F3(1),G(1)
            NP1=NOP-1
            DO 10 I=2,NP1
            X1=FLOAT(F1(I-1))+2.*FLOAT(F2(I-1))+FLOAT(F3(I-1))
            X2=FLOAT(F1(I+1))+2.*FLOAT(F2(I+1))+FLOAT(F3(I+1))
            DX=X1-X2
            DXS=DX*DX
            Y1=FLOAT(F1(I-1))+2.*FLOAT(F1(I))+FLOAT(F1(I+1))
            Y2=FLOAT(F3(I-1))+2.*FLOAT(F3(I))+FLOAT(F3(I+1))
            DY=Y1-Y2
            DYS=DY*DY
            S=SQRT(DXS+DYS)
            K=I-1
            IF(S.GT.2[illegible]6.)S=256.
            IF(S.LT.1.)S=1.
            G(K)=INT(S)
10          CONTINUE
            RETURN
            END
```

VIII.

```
C
C           NAME: [illegible].FOR
```

```
C       [illegible]: [illegible] C. Y[illegible]
C       DATE: [illegible], 1[illegible]81
C
        INTEGER F1([illegible]),F2([illegible]),F3([illegible]),F4([illegible]),G([illegible])
        [illegible]
10      FORMAT(/[illegible]X,'[illegible]/[illegible]',[illegible],[illegible]F1,[illegible]'/)
        [illegible],[illegible],[illegible],[illegible]F1,[illegible]
20      FORMAT(4I10)
        [illegible]=[illegible]-3
        [illegible]=[illegible]-3
        [illegible] [illegible] [illegible]OF1([illegible],[illegible],[illegible],[illegible])
        [illegible] [illegible] [illegible]OF2([illegible], [illegible],G,[illegible])
        K=[illegible]-[illegible]
        DO 30 I=[illegible],K
        [illegible]=I-1
        READ([illegible]'[illegible])(F1(K),K=1,[illegible])
        [illegible]=I
        READ([illegible]'[illegible])(F2(K),K=1,[illegible])
        [illegible]=I+1
        READ([illegible]'[illegible])(F3(K),K=1,[illegible])
        [illegible]=I+[illegible]
        READ([illegible]'[illegible])(F4(K),K=1,[illegible])
        CALL HG(F1,F2,F3,F4,G,[illegible])
        [illegible]2=I-1
        [illegible]([illegible]'[illegible]2)(G(K),K=1,[illegible])
        CALL [illegible]
30      [illegible]
        CALL [illegible]
        [illegible]
        SUBROUTINE HG(F1,F2,F3,F4,G,[illegible])
        INTEGER F1(1),F2(1),F3(1),F4(1),G(1)
        [illegible]=[illegible]-[illegible]
        DO 10 I=2,[illegible]
        J=I-1
        A=(ABS(FLOAT(F2(I))-FLOAT(F3(I+1)))+ABS(FLOAT(F3(I))-FLO
       1AT(F2(I+1))))/2.
        B=(ABS(FLOAT(F1(I-1))-FLOAT(F4(I+[illegible])))+ABS(FLOAT(F4(I-1))
       1-FLOAT(F1(I+[illegible]))))/2.
        C=(ABS(FLOAT(F1(I))-FLOAT(F4(I+1)))+ABS(FLOAT(F3(I-1))
       1-FLOAT(F[illegible](I+1))))/2.
        D=(ABS(FLOAT(F1(I+1))-FLOAT(F4(I)))+ABS(FLOAT(F[illegible](I-1))
       1-FLOAT(F3(I+[illegible]))))/2
        X=A[illegible]D
        [illegible]=[illegible](X)
        X[illegible]=[illegible]([illegible])
        G(J)=I[illegible]T([illegible])
10      CONTINUE
        RETURN
        END
```

IX.

```
C
C       [illegible]: [illegible]
C       PROG : [illegible] C. YEN
C       DATE: JUNE 1[illegible], 1981
```

```
      DIMENSION F(512),G(512)
      [illegible] F(256),[illegible](256),[illegible](256),[illegible],[illegible](256)
      TYPE 10
10    FORMAT([illegible]X,'I/F [illegible],[illegible],[illegible],[illegible],[illegible],[illegible],[illegible]'/)
      ACCEPT [illegible],[illegible],NOP,NOF1,[illegible],IG[illegible],[illegible],[illegible]
20    FORMAT([illegible])
      DEFINE FILE NOF1([illegible],[illegible],[illegible],[illegible])
      DO 30 I[illegible]=1,IGMAX
30    [illegible](I3)=[illegible].
      DO 70 I7=1,[illegible]OL
      [illegible]=I7
      READ([illegible]F1'LINE)(F(K),K=1,[illegible])
      IF(IG[illegible].[illegible].0)GO TO 50
      DO 40 I[illegible]=1,NOP
      L=F(I4)
      N(L)=N(L)+1
40    CONTINUE
      GO TO 70
50    DO 60 I6=1,NOP
      L=F(I6)+1
      [illegible](L)=[illegible](L)+1
60    CONTINUE
70    CONTINUE
      TOPTS=FLOAT([illegible]OL)*FLOAT(NOP)
      DO 80 I[illegible]=1,IGMAX
      F(I[illegible])=[illegible](I8)/TOPTS
80    CONTINUE
      CALL [illegible]
      IGS=IGRAY/[illegible]
      FIY=[illegible](IGRAY-IGS)
      DO 90 I[illegible]=1,IG[illegible]
      I99=(I[illegible]-1)*IGS
      [illegible](I9)=FLOAT(I99)/FIY
90    CONTINUE
      DO 110 I11=1,IGMAX
      [illegible]=0.
      DO 100 I[illegible]=1,I11
100   [illegible]=[illegible]+P(I10)
      [illegible](I11)=[illegible]
110   CONTINUE
      TYPE 105,(G(K),K=1,IGMAX)
105   FORMAT([illegible],[illegible]F12.5)
      CALL [illegible]
      DO 130 I13=1,IGMAX
      DO 120 I12=1,IGRAY
120   [illegible](I12)=ABS(G(I13)-R(I12))
      CALL MIN([illegible],IGRAY,M)
      [illegible](I13)=[illegible]([illegible])
130   CONTINUE
      TYPE 170,(H(K),K=1,IGMAX
170   FORMAT(/5X,5F7,3)
      CALL [illegible]
      DEFINE FILE NOF2(LOL,[illegible]OP,U,[illegible])
      FIG=FLOAT(IGMAX)
      DO 200 I[illegible]0=1,NOL
      LINE=I[illegible]0
      READ(NOF1'LINE)(F(K),K=1,[illegible])
```

```
          DO 190 I19=1,NOP
          G(I19)=I.. (..(F(I19))*F1C)
190       CONTINUE
          I.I.AX=I..
          WRITE(..'..,..SXA)(G(K),K=1, ..)
          CALL ....
200       CONTINUE
          CALL EXIT
          END
          SUBROUTINE ...MIN(A,L,M)
          REAL A(L)
          AMIN=A(1)
          DO 10 I=2,L
          IF(A(I).LT.AMIN)AMIN=A(I)
10        CONTINUE
          DO 20 I=1,L
          IF(A(I).NE.AMIN)GO TO 20
          M=I
20        CONTINUE
          RETURN
          END


X

C
C         NAME: PRE...FOR
C         PROG: ROBERT C. YEN
C         DATE: JUNE 14, 1981
C
          INTEGER F1(512),F2(512),F3(512),G(512),..(9)
          INTEGER D0(9),D1(9),D2(9),D3(9),D4(9),D5(9),D6(9),D7(9),X(9)
          DATA D0/1,1,1,1,-2,1,-1,-1,-1/
          DATA D1/1,1,1,1,-2,-1,1,-1,-1/
          DATA D2/1,1,-1,1,-2,-1,1,1,-1/
          DATA D3/1,-1,-1,1,-2,-1,1,1,1/
          DATA D4/-1,-1,-1,1,-2,1,1,1,1/
          DATA D5/-1,-1,1,-1,-2,1,1,1,1/
          DATA D6/-1,1,1,-1,-2,1,-1,1,1/
          DATA D7/1,1,1,-1,-2,1,-1,-1,1/
          TYPE 10
10        FORMAT(/,X,'1/P ..OL,NOP,NOP1,NOP2'/)
          ACCEPT ..,...,NOP,NOP1,NOP2
20        FORMAT(10I10)
          DEFINE FILE NOP1(NOL,NOP,U,LINE1)
          NOL2=NOL-2
          NOP2=NOP-2
          DEFINE FILE NOP2(NOL..,NOP..,U,LINE2)
          DO 40 I4=1,NOL2
          LINE1=I4
          READ(NOP1'LINE1)(F1(K),K=1,NOP)
          LINE1=I4+1
          READ(NOP1'LINE1)(F2(K),K=1,NOP)
          LINE1=I4+2
          READ(NOP1'LINE1)(F3(K),K=1,NOP)
          DO 30 I5=1,NOP2
```

```
      I31=I3+1
      I32=I3+2
      CALL CHANGE(F1(I3),F1(I31),F1(I32),F2(I3),F2(I31),F2(I32)
     1,F3(I3),F3(I31),F3(I32),S)
      CALL ML(S,D0,X(1))
      CALL ML(S,D1,X(2))
      CALL ML(S,D2,X(3))
      CALL ML(S,D3,X(4))
      CALL ML(S,D4,X(5))
      CALL ML(S,D5,X(6))
      CALL ML(S,D6,X(7))
      CALL ML(S,D7,X(8))
      CALL MAXVAL(X,M)
      G(I3)=M
30    CONTINUE
      LINE2=I4
      WRITE(NOF2'LINE2)(G(K),K=1,NOP2)
      CALL BELL
40    CONTINUE
      CALL EXIT
      END
      SUBROUTINE CHANGE(N1,N2,N3,N4,N5,N6,N7,N8,N9,L)
      INTEGER L(1)
      L(1)=N1
      L(2)=N2
      L(3)=N3
      L(4)=N4
      L(5)=N5
      L(6)=N6
      L(7)=N7
      L(8)=N8
      L(9)=N9
      RETURN
      END
      SUBROUTINE ML(S,R,M)
      INTEGER S(1),R(1)
      M=0
      DO 10 I=1,9
      M=M+S(I)*R(I)
10    CONTINUE
      RETURN
      END
      SUBROUTINE MAXVAL(X,M)
      INTEGER X(1)
      M=X(1)
      DO 10 I=2,8
      IF(X(I).GT.M)M=X(I)
10    CONTINUE
      RETURN
      END
```

XI.

```
C
C         NAME: LOCAL.FOR
C         PRGR: ROBERT C. YEN
```

```
C          DATE: JUNE 28, 1981
C
           INTEGER F1(512),F2(512),F3(512),G(512)
           TYPE 10
10         FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2'/)
           ACCEPT 20,NOL,NOP,NOF1,NOF2
20         FORMAT(4I10)
           DEFINE FILE NOF1(NOL,NOP,U,LINE1)
           NOL2=NOL-2
           NOP2=NOP-2
           DEFINE FILE NOF2(NOL2,NOP2,U,LINE2)
           DO 60 I6=1,NOL2
           LINE1=I6
           READ(NOF1'LINE1)(F1(K),K=1,NOP)
           READ(NOF1'LINE1)(F2(K),K=1,NOP)
           READ(NOF1'LINE1)(F3(K),K=1,NOP)
           DO 50 I5=1,NOP2
           I52=I5+2
           ISUM=0
           DO 30 I3=I5,I52
30         ISUM=ISUM+F1(I3)
           DO 40 I4=I5,I52
40         ISUM=ISUM+F3(I4)
           ISUM=ISUM+F2(I5)+F2(I52)
           SUM=FLOAT(ISUM)*.125
           ISUM=INT(SUM)
           III=F2(I5+1)-ISUM
           G(I5)=256-III
50         CONTINUE
           LINE2=I6
           WRITE(NOF2'LINE2)(G(K),K=1,NOP2)
           CALL BELL
           CALL EXIT
           END
```

XII.

```
C
C          NAME: THSHO.FOR
C          PRGR: ROBERT C. YEN
C          DATE: JUNE 28, 1981
C
           INTEGER F(512),G(512),TH
           TYPE 10
10         FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2,TH'/)
           ACCEPT 20,NOL,NOP,NOF1,NOF2,TH
20         FORMAT(5I10)
           DEFINE FILE NOF1(NOL,NOP,U,LINE1)
           DEFINE FILE NOF2(NOL,NOP,U,LINE2)
           DO 40 I4=1,NOL
           LINE1=I4
           READ(NOF1'LINE1)(F(K),K=1,NOP)
           DO 30 I3=1,NOP
           IF(F(I3).GT.TH)G(I3)=256
           IF(F(I3).LE.TH)G(I3)=1
```

```
30        CONTINUE
          LINE2=I
          WRITE(NOF2'LINE2)(G(K),K=1,NOP)
          CALL BELL
40        CONTINUE
          CALL EXIT
          END
```

XIII.

```
C
C         NAME: ANOS.FOR
C         PRGR: ROBERT C. YEN
C         DATE: MAY 24, 1981
C
          INTEGER F(512)
          TYPE 10
10        FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2,VAR,I1,I2'/)
          ACCEPT 20,NOL,NOP,NOF1,NOF2,VAR,I1,I2
20        FORMAT(4I10,F12.5,2I10)
          DEFINE FILE NOF1(NOL,NOP,U,LINE1)
          DEFINE FILE NOF2(NOL,NOP,U,LINE2)
          DO 40 I=1,NOL
          LINE1=I
          READ(NOF1'LINE1)(F(K),K=1,NOP)
          DO 30 J=1,NOP
          CALL GAUSS(S,VAR,I1,I2)
          IFN=F(J)+INT(S)
          IF(IFN.GT.256.OR.IFN.LT.1)IFN=F(J)
          F(J)=IFN
30        CONTINUE
          LINE2=I
          WRITE(NOF2'LINE2)(F(K),K=1,NOP)
          CALL BELL
40        CONTINUE
          CALL EXIT
          END
          SUBROUTINE GAUSS(T,S,I1,I2)
          T=0.
          DO 10 I=1,48
          T=T+RAN(I1,I2)
10        CONTINUE
          T=T-24.
          T=T*.5
          T=T*S
          RETURN
          END
```

XIV.

```
C
C         NAME: ALPHA.FOR
C         PRGR: ROBERT C. YEN
```

```
C         DATE: MAY 1, 1981
C
          INTEGER F(512),PF(512)
          TYPE 10
10        FORMAT(/5X,'I/P NOL,NOP,NOF'/)
          ACCEPT 20,NOL,NOP,NOF
20        FORMAT(3I10)
          DEFINE FILE NOF(NOL,NOP,U,LINE)
          C1=0.
          C2=0.
          C3=0.
          C4=0.
          C5=0.
          C6=0.
          C7=0.
          D=FLOAT(NOL-1)*FLOAT(NOP-1)
          LINE=1
          READ(NOF'LINE)(PF(K),K=1,NOP)
          DO 50 J=2,NOL
          READ(NOF'LINE)(F(K),K=1,NOP)
          DO 30 I=2,NOP
          C1=FLOAT(F(I))+C1
          C2=FLOAT(F(I-1))+FLOAT(PF(I))+C2
          C3=FLOAT(F(I-1))*FLOAT(F(I))+C3
          C4=FLOAT(PF(I))*FLOAT(F(I))+C4
          C5=FLOAT(F(I-1))*FLOAT(F(I-1))+C5
          C6=FLOAT(F(I-1))*FLOAT(PF(I))+C6
          C7=FLOAT(PF(I))*FLOAT(PF(I))+C7
30        CONTINUE
          DO 40 K=1,NOP
40        PF(K)=F(K)
50        CONTINUE
          BETA=(C3+C4)/(C5+2.*C6+C7)
          XMEAN=C1/D
          ZMEAN=C2/D
          ALPHA=XMEAN-BETA*ZMEAN
          TYPE 60,ALPHA,BETA
60        FORMAT(//5X,'ALPHA=',F15.5,5X,'BETA=',F15.5/)
          CALL BELL
          CALL EXIT
          END
```

XV.

```
C
C         NAME: ARMA.FOR
C         PRGR: ROBERT C. YEN
C         DATE: MAY 1, 1981
C
          INTEGER F(512),PF(512)
          TYPE 10
10        FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2,ALPHA,BETA'/)
          ACCEPT 20,NOL,NOP,NOF1,NOF2,ALPHA,BETA
20        FORMAT(4I5,2F12.5)
          DEFINE FILE NOF1(NOL,NOP,U,LINE1)
          NOL2=NOL-1
```

```
      DEFINE FILE NOF2(NOL2,NOP,U,LINE2)
      LINE1=1
      READ(NOF1'LINE1)(PF(K),K=1,NOP)
      DO 40 I=2,NOL
      LINE1=I
      READ(NOF1'LINE1)(F(K),K=1,NOP)
      CALL AUTO(ALPHA,BETA,F,PF,NOP)
      LINE1=I
      READ(NOF1'LINE1)(PF(K),K=1,NOP)
      DO 30 J=1,NOP
      IF(F(J).GT.256)F(J)=256
      IF(F(J).LT.1)F(J)=1
30    CONTINUE
      LINE2=I-1
      WRITE(NOF2'LINE2)(F(K),K=1,NOP)
40    CONTINUE
      CALL EXIT
      END
      SUBROUTINE AUTO(ALPHA,BETA,F,PF,NF)
      INTEGER F(1),PF(1)
      REAL RF(512)
      DO 10 I=2,NF
      RF(I)=ALPHA+BETA*(FLOAT(F(I-1))+FLOAT(PF(I)))
10    CONTINUE
      RF(1)=RF(2)
      DO 20 I=1,NF
      F(I)=INT(RF(I))
20    CONTINUE
      RETURN
      END
```

XVI.

```
C
C     NAME: KALMAN.FOR
C     PRGR: ROBERT C. YEN
C     DATE: MAY 1, 1981
C
      INTEGER F(512)
      TYPE 10
10    FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2'/)
      ACCEPT 20,NOL,NOP,NOF1,NOF2
20    FORMAT(4I10)
      TYPE 30
30    FORMAT(/5X,'I/P FKL,GKL,HKL,RKL,QKL,XIKL,PIKL'/)
      ACCEPT 40,FKL,GKL,HKL,RKL,QKL,XIKL,PIKL
40    FORMAT(10F12.5)
      DEFINE FILE NOF1(NOL,NOP,U,LINE1)
      DEFINE FILE NOF2(NOL,NOP,U,LINE2)
      DO 50 I=1,NOL
      LINE1=I
      READ(NOF1'LINE1)(F(K),K=1,NOP)
      CALL KALMAN(F,NOP,FKL,GKL,HKL,RKL,QKL,XIKL,PIKL)
      LINE2=I
      WRITE(NOF2'LINE2)(F(K),K=1,NOP)
      CALL BELL
```

```
50      CONTINUE
        CALL EXIT
        END
        SUBROUTINE KALMAN(Y,NF,F,G,H,R,Q,XI,PI)
        INTEGER Y(1)
        Z=FLOAT(Y(1))
        GAIN=F*PI*H/(H*PI*H+R)
        XN=(F-GAIN*H)*XI+GAIN*Z
        PN=F*(PI-PI*H/(H*PI*H+R)*H*PI)*F+G*Q*G
        X=XI+PI*H/(H*PI*H+R)*(Z-H*XI)
        Y(1)=INT(X)
        XO=XN
        PO=PN
        DO 10 K=2,NF
        Z=FLOAT(Y(K))
        GAIN=F*PO*H/(H*PO*H+R)
        XN=(F-GAIN*H)*XO+GAIN*Z
        PN=(F*GAIN*H/(H*PO*H+R)*H*PO)*F+G*Q*G
        X=XO+PO*H/(H*PO*H+R)*(Z-H*XO)
        Y(K)=INT(X)
        XO=XN
        PO=PN
10      CONTINUE
        RETURN
        END
```

XVII.

```
C
C       NAME: VH.FOR
C       PRGR: ROBERT C. YEN
C       DATE: MAY 1, 1981
C
        INTEGER F(512),A(512)
        TYPE 10
10      FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2'/)
        ACCEPT 20,NOL,NOP,NOF1,NOF2
20      FORMAT(4I10)
        TYPE 30
30      FORMAT(/5X,'I/P FKL,GKL,HKL,XIKL,RV,QV,PIV'/)
        ACCEPT 40,FKL,GKL,HKL,XIKL,RV,QV,PIV
40      FORMAT(10F12.5)
        DEFINE FILE NOF1(NOL,NOP,U,LINE1)
        DEFINE FILE NOF2(NOP,NOL,U,LINE2)
        DO 70 J=1,NOP
        DO 50 I=1,NOL
        LINE1=I
        READ(NOF1'LINE1)(F(K),K=1,NOP)
        A(I)=F(J)
50      CONTINUE
        CALL KALMAN(A,NOP,FKL,GKL,HKL,RV,QV,XIKL,PIV)
        LINE2=J
        WRITE(NOF2'LINE2)(A(K),K=1,NOL)
        CALL BELL
70      CONTINUE
        CALL EXIT
        END
```

XVIII.

```
C
C          NAME: OPT.FOR
C          PROG: ROBERT C. YEN
C          DATE: MAY 10, 1981
C
           INTEGER A1(256),A2(256),A3(256),A4(256),A5(256),A6(256)
           DOUBLE PRECISION C,Z,Y,D1,WK,A,B(256),G(50),W(50)
           DOUBLE PRECISION B1(256),B2(256),B3(256),B4(256),B5(256)
           TYPE 10
10         FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2'/)
           ACCEPT 20,NOL,NOP,NOF1,NOF2
20         FORMAT(4I10)
           TYPE 30
30         FORMAT(/5X,'I/P W1,WK,D1'/)
           ACCEPT 40,W1,WK,D1
40         FORMAT(3F12.5)
           DEFINE FILE NOF1(NOL,NOP,U,LINE1)
           M=5
           NOL2=NOL-M+1
           NOP2=NOP-M+1
           DEFINE FILE NOF2(NOL2,NOP2,U,LINE2)
           N1=(M+1)/2
           Z=0.D0
           DO 130 K=2,32
           W(1)=W1
130        W(K)=WK
           DO 500 I=1,NOL2
           LINE1=I
           READ(NOF1'LINE1)(A1(IK),IK=1,NOP)
           READ(NOF1'LINE1)(A2(IK),IK=1,NOP)
           READ(NOF1'LINE1)(A3(IK),IK=1,NOP)
           READ(NOF1'LINE1)(A4(IK),IK=1,NOP)
           READ(NOF1'LINE1)(A5(IK),IK=1,NOP)
           DO 300 L=1,NOP
           B1(L)=A1(L)
           B2(L)=A2(L)
           B3(L)=A3(L)
           B4(L)=A4(L)
           B5(L)=A5(L)
300        CONTINUE
           DO 750 L=1,NOP2
           DO 800 K=1,M
           G(K)=B1(L+K-1)
           G(K+M)=B2(L+K-1)
           G(K+2*M)=B3(L+K-1)
           G(K+3*M)=B4(L+K-1)
           G(K+4*M)=B5(L+K-1)
800        CONTINUE
           M2=M*M
           DO 810 K=1,M2
810        C=C+G(K)
           C=C/M2
           DO 820 K=1,M2
820        G(K)=G(K)-C
           DO 840 K=1,M2
840        Z=Z+W(K)*G(K)
```

```
         E=G((M2+1)/2)-[illegible]
830      W(K)=W(K)+E*D1*G(K)
         W((M2+1)/2)=0.D0
         B(L)=S+C-SN/2.D0
         C=0.D0
750      S=0.D0
         DO 240 L=1,NOP2
         A6(L)=IDINT(B(L))
240      CONTINUE
         LINE2=1
         WRITE(LOPZ'LINE2)(A6(IK),IK=1,NOP2)
         CALL [illegible]
[illegible]00      CONTINUE
900      CALL EXIT
         END
```

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